

Hippocampal-neocortical interactions, up-states, and fast-forward replay of neocortical memory episodes

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The hippocampal output vector spans a subspace that is determined by spatial location. Within that subspace, both intrinsic neural activity (e.g., working memory, motivation, goals, behavioral set etc.) and external input (sensory cues) modify the direction of the population vector. Thus, hippocampus provides a context code to the neocortex that is jointly determined by what is happening and where it happens, with the latter factor dominant. These hippocampal context or 'index' codes are believed to link memory items stored in parameter specific, relatively sparsely interconnected neocortical modules by indirect association. The superficial layers of the neocortex, which receive the main hippocampal outflow, are similarly sensitive to spatial context (consistent with the need to store index codes in the neocortex at the time the memory is acquired), whereas deeper neocortex layers are relatively context independent (and thus contain the stored data in a context free form). It appears that the initially sparse hippocampal output code is 'zipped' for more efficient transmission in the CA1-subiculum transformation, and 'unzipped' to sparse form again for storage in superficial neocortex.

During slow-wave sleep and quiet wakefulness, hippocampal sharp-wave-ripple events (lasting about 50-100 msec) convey bursts of recently stored index sequences to the neocortex, and may trigger transitions from 'down' states to 'up' states, during which some form of memory reprocessing may occur. During 'up' states, some neocortical areas can exhibit high fidelity replay of temporal sequences of neural ensemble activity, compressed in time by a factor of about 5-7 fold. Only forward replay is observed, not reverse. The emerging picture is one in which the hippocampus, in slow-wave sleep, periodically (randomly) seeds the neocortex with snippets (100 msec) of recently stored index code sequences, which triggers more temporally extended sequence replay (500 msec) of cortically stored data, corresponding to several seconds of real time. What happens to cortical information structures as a consequence of this process is mostly still a matter of speculation, falling under the general theme of 'systems-level memory consolidation'.